Geographic variation in the volatile leaf oils of *Juniperus procera* Hochst. ex. Endl.

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ABSTRACT

Comparisons of the leaf components for four populations of *J. procera* are reported. The major components of the oils are α-pinene (17.7 to 37.4%), δ-3-carene (8.1 - 28.7%), terpinolene (1.8 - 4.3%), elemol (1.4 - 6.2%), abietadiene (0.6 - 11.8%) and trans-totarol (1.3% - 11.0%). There appears to be a North - South cline of variation from Abha, Saudi Arabia to Ethiopia to Kijabe, Kenya (cf. -pinene, -3-carene, elemol, abietadiene and trans-totarol. However, the population at Thika does not fit the trend and is very unusual in all the major components. It was observed that a considerable number of trees were planted in the Thika area and perhaps the samples of 'native' trees were in fact obtained from cultivated trees. Published on-line: **www.phytologia.org** *Phytologia 95(4):269-273 (Nov. 1, 2013).*
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KEY WORDS: *Juniperus procera,* geographic variation, leaf oils, terpenes.

Juniperus procera Hochst. ex. Endl. is the only juniper that grows naturally in both the northern and southern hemispheres; all other *Juniperus* species are confined to the northern hemisphere (Adams, 2011). *Juniperus procera* consists of two major populations: in Saudi Arabia/ Yemen and the high mountains of east Africa (Fig. 1). The species is thought to have originated from *J. excelsa,* or an ancestor that migrated southward into the Rift Mountains of east Africa (Adams, Demeke and Abulfatih, 1993).

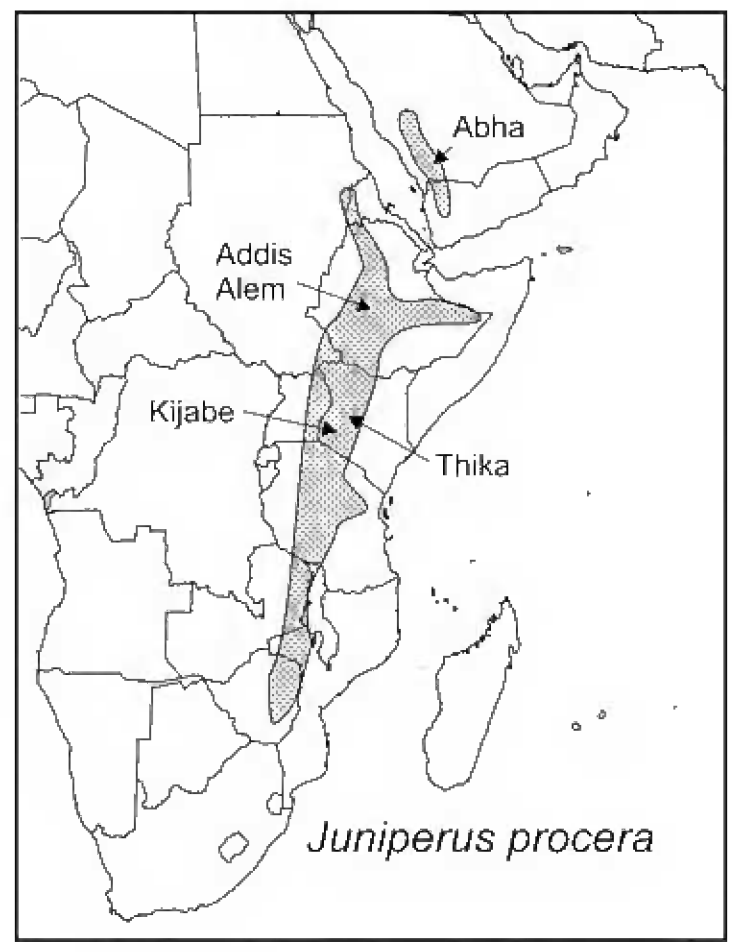

Fig. 1. Distribution of *J. procera* with populations sampled.

The volatile leaf oils have been reported upon, and literature reviewed by Adams (1990). The purpose of this paper is to present an updated analyses of the oils and geographic variation in east Africa and Saudi Arabia.

MATERIALS AND METHODS

Plant material - *J. excelsa: Adams 13193 (9433-9435),* Eskisehir, Turkey, *J. procera*: *Adams 6190-6193*, ex. H. A. Abulfatih, Abha, Saudi Arabia, ca. 18° 13' N, 42° 30' E, 7300 ft., *Adams 6184-6188*, near Addis Alem, Ethiopia, 40 km west of Addis Ababa on road to Guder, 2400 m, ca. 9° 02' N, 38° 23' E, 2400m; *Adams 5333-5335*, near Thika, 38 km nw of Nairobi, Kenya, ca. 1° 02' N, 37° 03' E, 2170m; *Adams 6007-6009*, Kijabe, near Rift Valley Academy, ca. 0° 56' N, 36° 36' E, 7300 ft. Voucher specimens deposited in the Herbarium, Baylor University (BAYLU).

Fresh or air dried (100 g) leaves were steam distilled for 2 h using a circulatory Clevenger-type apparatus (Adams, 1991). The oil samples were concentrated (diethyl ether trap removed) with nitrogen and the samples stored at -20° C until analyzed. The extracted leaves were oven dried (48h, 100° C) for the determination of oil yields. The oils were analyzed on a HP5971 MSD mass spectrometer, scan time

1/ sec., directly coupled to a HP 5890 gas chromatograph, using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column (see Adams, 2007 for operating details). Identifications were made by library searches of our volatile oil library (Adams, 2007), using the HP Chemstation library search routines, coupled with retention time data of authentic reference compounds. Quantitation was by FID on an HP 5890 gas chromatograph using a J & W DB-5, 0.26 mm x 30 m, 0.25 micron coating thickness, fused silica capillary column using the HP Chemstation software.

RESULTS AND DISCUSSION

Comparisons of the leaf components for the four populations are given in Table 1. The major components of the oils are α-pinene (17.7 to 37.4%), δ-3-carene (8.1 - 28.7%), terpinolene (1.8 - 4.3%), elemol (1.4 - 6.2%), abietadiene (0.6 - 11.8%) and trans-totarol (1.3% - 11.0%). There appears to be a North - South cline of variation from Abha, Saudi Arabia to Ethiopia to Kijabe, Kenya (cf. -pinene, -3-carene, elemol, abietadiene and trans-totarol (Table 1). However, the population at Thika does not fit the trend and is very unusual in all the major components (Table 1). It was observed that a considerable number of trees were planted in the Thika area and perhaps my samples of 'native' trees were in fact cultivated. The seed source of the trees at Thika is not known.

The presence of cedrol (very common in the related, *J. excelsa* oil, see Table 1) is only 0.4% in the Abha samples and missing or just a trace in all the other samples (Table 1). It is tempting to speculate that the Abha population harbors some genes from *J. excelsa* from ancient hybridization with *J. excelsa.* Additional research is needed to support such conjecture.

It is also noteworthy that *J. procera* has been the source of East African cedarwood oil in the past (Adams, 1991). The heartwood oil is reported to contain 41.8% α-cedrene and 41.8% cedrol (Pettersson and Runeberg, 1961). But, as in the case with most *Juniperus* species, the leaf oil of *J. procera* contains an entirely different set of terpenoids than found in the heartwood oil. The heartwood oil components (cf. α-cedrene β-cedrene, thujopsene, cuparene, cedrol, widdrol, etc.) are nearly all absent in *J. procera* leaf oil, in contrast to *J. excelsa* (Table 1), *J. foetidissima, J. polycarpos, J. seravschanica* and *J. turcomanica* whose leaf oils contain large amounts of cedrol, etc. (Adams 2011).

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Table 1. Leaf essential oils for populations of *J. procera*. The leaf oil of *J. excelsa*, Turkey is added as a comparison. Components that tend to separate the *J. procera* populations are highlighted in boldface.

KI	Compound	Abha, S. A.	Addis Alem	Kijabe, Kenya	Thika, Kenya	*excelsa* Turkey
921	tricyclene	t	t	t	t	0.2
924	α-thujene	t	t	t	t	t
932	**α-pinene**	**21.2**	**32.6**	**37.4**	**17.7**	**41.7**
945	α-fenchene	1.0	1.1	0.8	0.2	0.3
946	camphene	0.1	0.2	0.3	0.2	0.2
961	verbenene	t	0.1	0.1	t	t
969	sabinene	t	t	t	0.7	0.1
974	1-octen-3-ol	0.2	0.3	0.8	1.2	-
974	β-pinene	2.1	3.1	3.7	2.2	0.7
988	myrcene	3.1	3.1	3.9	2.3	1.2
1002	α-phellandrene	t	t	t	t	0.1
1008	**δ-3-carene**	**28.7**	**28.6**	**21.6**	**8.1**	**5.3**
1014	α-terpinene	t	t	t	t	0.1
1020	p-cymene	0.3	0.2	0.2	t	0.6
1024	limonene	0.8	0.5	t	0.8	1.2
1025	β-phellandrene	1.5	1.4	2.3	0.8	0.9
1044	(E)-β-ocimene	t	t	t	t	t
1054	γ-terpinene	0.2	t	0.1	0.2	0.5
1086	**terpinolene**	**4.3**	**3.2**	**2.3**	**1.8**	**1.1**
1095	linalool	1.1	0.6	0.3	1.7	-
1108	p-1,3,8-menthatriene	t	0.1	t	t	-
1118	cis-p-menth-2-en-1-ol	t	t	t	t	0.1
1122	α-campholenal	t	t	t	t	0.5
1132	cis-limonene oxide	t	0.2	t	t	-
1135	trans-pinocarveol	t	t	t	t	0.8
1137	trans-verbenol	0.2	0.1	t	0.3	0.2
1141	camphor	t	t	t	0.3	1.2
1145	camphene hydrate	-	-	-	-	0.1
1165	borneol	t	0.1	t	0.5	-
1166	p-mentha-1,5-dien-8-ol	t	t	t	t	-
1172	cis-pinocamphone	t	t	t	t	0.2
1174	terpinen-4-ol	0.2	t	t	0.3	0.1
1178	naphthalene	t	t	t	0.3	0.1
1179	p-cymen-8-ol	t	t	t	t	0.1
1186	α-terpineol	0.4	0.3	t	1.1	t
1204	verbenone	-	-	-	-	0.2
1215	trans-carveol	-	-	-	-	0.2
1218	endo-fenchyl acetate	-	-	-	-	0.1
1249	piperitone	-	-	-	-	0.1
1274	pregeijerene B	1.2	0.6	t	0.5	-
1284	bornyl acetate	0.4	0.2	t	0.7	0.4
1291	(2E,4Z)-decadienal	-	-	-	-	0.1
1319	(2E,4E)-decadienal	-	-	-	-	2.4
1387	β-bourbonene	t	t	t	t	0.1

KI	Compound	Abha, S. A.	Addis Alem	Kijabe, Kenya	Thika, Kenya	*excelsa* Turkey
1389	β-elemene	t	t	t	t	-
1390	7-epi-sesquithujene	-	-	-	-	0.1
1410	α-cedrene	-	-	-	-	0.8
1413	β-funebrene	-	-	-	-	0.7
1417	**(E)-caryophyllene**	**3.0**	**0.8**	**0.3**	**1.0**	-
1419	β-cedrene	-	-	-	-	0.5
1429	cis-thujopsene	-	-	-	-	0.3
1451	trans-muurola-3,5-diene	-	-	-	-	0.1
1452	**α-humulene**	**3.8**	**1.1**	**0.5**	**1.5**	**0.1**
1454	(E)-β-farnesene	-	-	-	-	0.2
1469	β-acoradiene	-	-	-	-	0.2
1475	trans-cadina-1(6),4-diene	-	-	-	-	0.2
1480	**germacrene D**	**2.2**	**0.5**	**0.2**	**0.7**	**0.6**
1493	trans-muurola-4(14),5-diene	-	-	-	-	0.2
1493	epi-cubebol	-	-	-	-	0.3
1496	valencene	-	-	-	-	0.3
1500	β-himachalene	-	-	-	-	0.1
1504	cuparene	-	-	-	-	0.1
1506	(Z)-α-bisabolene	-	-	-	-	0.1
1512	α-alaskene	-	-	-	-	0.2
1513	γ-cadinene	t	t	t	t	-
1514	cubebol	-	-	-	-	0.4
1521	trans-calamenene	-	-	-	-	0.2
1522	δ-cadinene	0.3	t	t	t	0.3
1532	γ-cuparene	-	-	-	-	0.2
1548	**elemol**	-	-	-	-	-
1574	germacrene D-4-ol	0.2	0.1	t	t	-
1589	allo-cedrol	-	-	-	-	1.9
1600	**cedrol**	**0.4**	-	**t**	-	**25.4**
1608	humulene epoxide II	0.6	0.3	0.3	0.7	t
1608	-oplopenone	-	-	-	-	t
1627	1-epi-cubenol	-	-	-	-	0.5
1630	γ-eudesmol	0.8	0.6	0.3	1.5	-
1632	β-acorenol	-	-	-	-	0.1
1638	epi-α-cadinol	t	t	t	t	t
1640	epi-α-muurolol	t	t	t	t	t
1645	cubenol	-	-	-	-	0.1
1649	β-eudesmol	1.1	0.7	0.5	1.5	-
1652	α-eudesmol	1.6	0.9	0.7	2.2	-
1653	α-cadinol	-	-	-	-	t
1661	sesquiterpene, 85,57,41,238	-	-	-	-	1.0
1668	β-atlantone	-	-	-	-	0.6
1670	bulnesol	0.5	0.3	t	0.6	-
1685	germacra-4(15),5,10-trien-1-al	t	0.1	t	0.4	-
1713	cedroxyde	-	-	-	-	0.1
1792	8-α-acetoxyelemol	0.9	1.0	0.6	2.3	-
1958	iso-pimara-8(14),15-diene	t	0.2	t	0.3	-

KI	Compound	Abha, S. A.	Addis Alem	Kijabe, Kenya	Thika, Kenya	*excelsa* Turkey
1987	**manoyl oxide**	**0.3**	**3.3**	**1.1**	**0.7**	**0.1**
2055	abietatriene	0.2	0.2	0.5	1.4	t
2087	**abietadiene**	**0.6**	**1.9**	**4.0**	**11.8**	**-**
2105	iso-abienol	t	0.8	5.2	1.9	-
2153	abieta-8(14),13(15)-diene	t	t	0.1	0.3	-
2181	sandaracopimarinal	0.2	0.1	0.2	0.8	-
2269	sandaracopimarinol	t	0.1	0.2	0.6	-
2282	sempervirol	0.2	0.2	0.3	0.9	-
2298	4-epi-abietal	1.8	0.8	0.6	1.4	0.2
2314	**trans-totarol**	**1.3**	**2.4**	**3.7**	**11.0**	**-**
2331	trans-ferruginol	0.4	0.5	1.0	2.6	-
2401	abietol	0.2	0.1	t	0.2	-